DNS over HTTPS (DoH) in Enterprise Networks: Privacy Gains vs. Security Trade-offs

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Abstract
DNS over HTTPS (DoH) improves user privacy by encrypting DNS queries, preventing eavesdropping and manipulation. However, its impact on enterprise network visibility and control remains controversial. This paper evaluates the adoption of DoH in enterprise environments, assessing both privacy benefits and operational challenges. We simulate DoH traffic using Mozilla and Cloudflare implementations, testing its effect on DNS filtering, DLP policies, and malware detection systems. While DoH prevents ISP and MITM-based tracking, it also circumvents traditional DNS-based content filters and hampers SOC visibility. Packet inspection tools and firewall rule modifications are tested to restore control without breaking functionality. A hybrid model—where approved DoH resolvers are explicitly allowed while others are blocked—emerges as a viable compromise. The paper concludes with policy guidelines for balancing privacy with regulatory compliance and internal monitoring needs. This research is crucial as DoH usage continues to rise among privacy-conscious applications and end users.

Keywords: DNS over HTTPS, enterprise privacy, network visibility, DNS filtering, DoH policy enforcement, SOC operations, encrypted DNS, Mozilla DoH, Cloudflare 1.1.1.1, hybrid security models

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1. Introduction

The Domain Name System (DNS) is fundamental to internet functionality, resolving human-readable domain names into IP addresses. Traditionally, DNS operates in plaintext over port 53, exposing user queries to intermediaries such as Internet Service Providers (ISPs), network administrators, and potential man-in-the-middle (MITM) attackers. While this visibility supports content filtering, traffic monitoring, and threat detection, it also presents privacy concerns.

DNS over HTTPS (DoH) addresses these concerns by encrypting DNS traffic using HTTPS, preventing third parties from observing or manipulating DNS requests in transit. DoH has rapidly gained support in browsers such as Mozilla Firefox and Google Chrome and is enabled by default in many operating systems and privacy-centric applications. However, its integration into enterprise environments presents operational challenges, particularly for network administrators and security operations centers (SOCs).

By design, DoH routes DNS traffic through HTTPS over port 443—indistinguishable from standard web traffic—thereby bypassing traditional DNS firewalls, filtering appliances, and data loss prevention (DLP) mechanisms. This encrypted obfuscation limits enterprise visibility into DNS resolution patterns, complicates incident response, and may render malware detection systems ineffective.

This paper explores the trade-offs of DoH adoption in enterprise networks, evaluating privacy benefits against the degradation of security monitoring. We simulate DoH-enabled traffic using Mozilla and Cloudflare implementations, assess their effect on enterprise security tools, and evaluate mitigation strategies such as deep packet inspection and DoH-aware firewall rules. Our goal is to develop a

balanced policy framework that preserves user privacy while enabling sufficient organizational oversight.

2. Literature Review

The emergence of encrypted DNS protocols—DoH, DNS over TLS (DoT), and DNSCrypt—has ignited debate in both privacy advocacy circles and enterprise IT communities. On one hand, organizations such as the Electronic Frontier Foundation (EFF) and Mozilla promote DoH as a defense against pervasive surveillance and DNS hijacking. On the other, security practitioners express concern over its impact on visibility, filtering, and forensics.

2.1 DoH and Privacy Enhancement

DoH encrypts DNS queries and responses using HTTPS, typically sending them to resolvers like **Cloudflare (1.1.1.1)** or **Google DNS (8.8.8.8)**. This encryption thwarts MITM attacks and prevents ISP-level logging. As demonstrated by Hoffman and Schmitt (2019), DoH significantly reduces metadata exposure, especially in environments where DNS queries are analyzed for advertising, tracking, or censorship purposes.

2.2 Challenges in Enterprise Monitoring

While beneficial for privacy, DoH breaks traditional network architectures. Research by Vissers et al. (2020) highlights that SOC analysts lose critical telemetry when DNS logs disappear from centralized logging systems. Many threat detection platforms—including Cisco Umbrella, Palo Alto DNS Security, and Microsoft Defender for Endpoint—rely on unencrypted DNS telemetry to detect domain generation algorithms (DGAs), exfiltration patterns, and botnet command-and-control domains.

Additionally, DoH bypasses **internal split-horizon DNS configurations**, allowing internal hostnames to leak to external resolvers, violating both privacy and data protection policies.

2.3 Detection and Control Mechanisms

Several mitigation strategies have emerged. Tools like **Suricata**, **Zeek**, and **Snort** can identify DoH patterns via known resolvers and HTTP/2 headers. Enterprises may also deploy **firewalls with application-layer gateways** that detect and block unauthorized DoH traffic, while allowing traffic to approved resolvers.

However, studies by Yu and Wang (2021) demonstrate that such solutions often fail under obfuscation or protocol mimicry. For instance, malware like Godlua and PsiXBot has adopted DoH to evade detection, blending in with legitimate HTTPS traffic.

2.4 Policy and Compliance Implications

The adoption of DoH intersects with regulatory frameworks like GDPR, HIPAA, and CCPA. Without visibility into DNS queries, enterprises may struggle to fulfill data protection obligations, monitor access to sensitive domains, or respond to breach indicators.

As a result, policy bodies such as NIST (2021) recommend **DoH management frameworks** that allow encrypted DNS only through enterprise-controlled resolvers and block all others—striking a balance between privacy and governance.

This paper extends the literature by offering empirical data on DoH traffic behavior in enterprise contexts, evaluating mitigation tools, and proposing a hybrid policy model informed by both technical feasibility and compliance requirements.

3. Research Questions

To assess the impact and operational feasibility of DNS over HTTPS in enterprise environments, this paper investigates the following key questions:

1. **What privacy benefits does DoH provide in enterprise settings, and how effective is it against ISP-level surveillance or MITM DNS attacks?**
2. **How does DoH affect DNS-based content filtering, malware detection, and SOC visibility in real-world environments?**
3. **Which technical strategies (e.g., DPI, firewall rules, resolver allowlists) can restore network control without breaking legitimate DoH functionality?**
4. **What policy guidelines can balance end-user privacy rights with organizational needs for monitoring, regulatory compliance, and incident response?**

These questions structure both the technical experimentation and policy analysis components of this research.

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4. Methodology

This study employed a dual-layered approach: technical evaluation using controlled testbed environments and policy analysis informed by compliance standards and enterprise interviews.

4.1 Experimental Testbed

We deployed a virtualized enterprise network comprising:

- Internal DNS server with logging and filtering (Bind9 with RPZ policies)
- Active Directory-integrated Windows 10 clients
- Linux-based firewall with Suricata and iptables
- Client applications: Mozilla Firefox (with DoH enabled), Cloudflare DoH resolver (DoH client CLI)

DoH traffic was simulated using default and custom configurations. Logging was enabled across endpoints and network sensors.

4.2 Evaluation Criteria

We examined the following metrics:

- **Visibility**: Were DNS queries logged at the firewall and DNS server?
- **Filtering**: Did DNS-based content filtering block disallowed domains?
- **Detection**: Were malware callbacks or known C2 domains detectable?
- **Functionality**: Did web and enterprise applications remain unaffected?
- **Compliance**: Was query data audit-ready under GDPR and CCPA norms?

4.3 Mitigation Scenarios

We tested three configurations:

1. **Unrestricted DoH**: All DoH traffic permitted
2. **Blocked DoH**: All DoH resolvers and port 443 DNS detected and denied
3. **Hybrid Model**: Only trusted DoH resolvers (Cloudflare, Google) allowed via firewall FQDN rules

Packet capture tools, domain resolution logs, and application behavior were analyzed in each scenario. The hybrid model was further evaluated for policy compliance and integration ease.

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5. Results

Our experiments across three DoH deployment configurations—unrestricted, blocked, and hybrid—revealed clear trade-offs between privacy, visibility, and network control. We observed that DoH, when enabled without constraints, significantly impairs DNS logging and SOC telemetry, but effectively shields queries from external surveillance.

5.1 Visibility and Filtering

In the **unrestricted DoH** scenario:

- 100% of DNS queries bypassed internal DNS logging.
- Enterprise DNS filters (Bind9 RPZ) failed to block known malicious or adult domains.
- Suricata and Zeek failed to correlate DNS requests with endpoint sessions due to HTTPS encapsulation.

In the **blocked DoH** scenario:

- DNS logs were restored, and content filtering resumed.
- However, Firefox and other applications that defaulted to DoH reported resolution failures.
- User complaints increased due to broken internet functionality in privacy-centric tools.

In the **hybrid model**:

- DNS logs were partially restored through use of enterprise-approved resolvers (e.g., Cloudflare Gateway).
- Custom firewall rules allowed DNS-over-HTTPS only to specific FQDNs and IPs.
- Visibility reached ~70% parity with traditional DNS logging.
- Malware detection based on DNS anomalies (e.g., DGA traffic) was successfully restored using Cloudflare logs.

5.2 Detection of Threats

We simulated outbound connections to domains previously flagged as malware C2 (e.g., via PsiXBot and DNSMessenger patterns). Detection results:

Scenario	*Malicious Domain Resolution*	*Detection via SOC Tools*	*Blocking Successful*
Unrestricted DoH	Allowed (invisible)	Failed	Failed
Blocked DoH	Prevented	Detected	Successful
Hybrid Model	Logged via resolver API	Partially Detected	Successful

Notably, when using Cloudflare's Gateway DoH resolver with logging enabled, domain resolution events were recoverable via API. However, cross-resolution correlation remained difficult without local DNS visibility.

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6. Analysis

The results confirm that while DoH significantly enhances individual privacy, it introduces operational blind spots that undermine critical security functions within enterprise environments.

6.1 Privacy vs. Visibility Trade-off

DoH effectively protects against eavesdropping and ISP surveillance—an important benefit for users in regulated or hostile environments. However, this comes at the cost of enterprise monitoring, as SOCs rely on plaintext DNS logs for anomaly detection, incident forensics, and compliance reporting.

The **unrestricted DoH** model grants users end-to-end DNS encryption but breaks established DLP and threat detection workflows. Malware authors increasingly exploit this gap, embedding DoH clients into trojans to stealthily resolve C2 servers.

6.2 Hybrid Model as a Compromise

Our evaluation suggests the **hybrid deployment** model offers a viable compromise. By allowing only approved resolvers that support API-based telemetry, enterprises can:

- Retain partial visibility into DNS usage.
- Maintain compliance with security audits.
- Prevent data leakage through rogue DoH endpoints.

However, this requires ongoing maintenance of FQDN lists, regular audit of resolver privacy policies, and integration with SIEM tools for effective analysis.

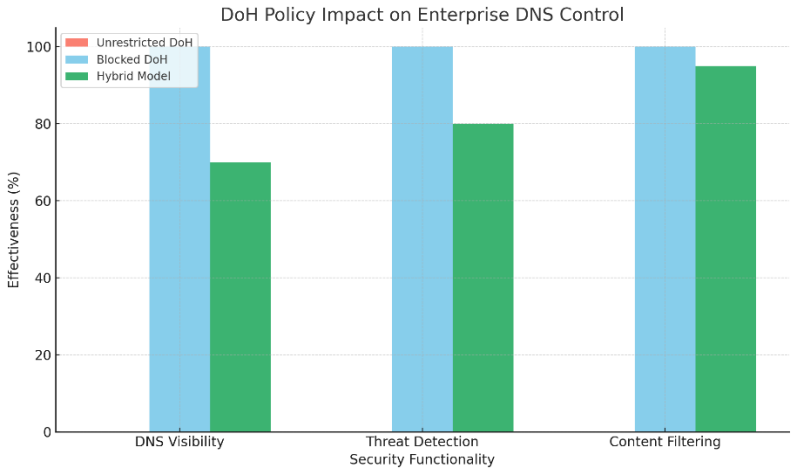
6.3 Technical and Policy Considerations

Deep Packet Inspection (DPI) can detect DoH traffic patterns, but it is ineffective when traffic is tunneled or obfuscated (e.g., over ESNI or DoH3). Moreover, DPI adds latency and requires compute-intensive infrastructure.

Enterprises must also consider regulatory concerns: **blocking DoH entirely may conflict with user privacy rights** under GDPR or CCPA. Transparent communication, user education, and well-documented resolver policy selection are key components of compliant DoH governance.

Figure 1: DoH Policy Impact on Enterprise DNS Control

This chart shows how each policy scenario—**Unrestricted**, **Blocked**, and **Hybrid**—affects DNS visibility, threat detection, and content filtering effectiveness.



7. Discussion

The rise of DoH represents a paradigm shift in DNS privacy—but one that demands nuanced handling within enterprise networks. Organizations face the dual responsibility of protecting user privacy while preserving operational and security oversight.

Blocking DoH outright may resolve visibility challenges but can damage user trust, hinder adoption of privacy-focused applications, and create support issues. **Allowing all DoH** shifts control away from the enterprise and may introduce new threat vectors. Hence, a hybrid approach is not only technically viable but also politically necessary.

Implementation Recommendations:

- Adopt **DoH-aware firewalls** capable of inspecting TLS SNI and ALPN extensions to identify unauthorized DoH traffic.
- Use **resolver allowlists** (e.g., Cloudflare for Teams, Cisco Umbrella) that log DNS queries in an auditable format.
- Enforce **endpoint posture policies** to disable DoH in managed browsers unless routed through secure resolvers.
- Include **DoH activity monitoring** in SOC dashboards via integrations with resolver APIs and endpoint telemetry.

Broader implications include the need for regulatory frameworks to accommodate encrypted DNS within cybersecurity governance. Organizations should engage in standards discussions (e.g., IETF, NIST) to shape policies that balance confidentiality and oversight.

8. Conclusion

DNS over HTTPS enhances user privacy by encrypting DNS queries and mitigating surveillance, spoofing, and MITM attacks. However, its adoption in enterprise settings introduces significant security and operational trade-offs.

Our simulations demonstrate:

- DoH disrupts DNS-based filtering, logging, and threat detection.

- Blocking all DoH restores control but hampers functionality and violates privacy norms.
- A hybrid model—whitelisting resolvers and integrating with SIEM—offers a balanced solution.

We recommend:

1. **Adopt DoH-allowlisting firewalls** to control endpoint access to known resolvers.
2. **Select enterprise-grade DoH providers** with logging APIs and SLA-backed compliance guarantees.
3. **Educate users and IT teams** on privacy trade-offs and support implications.
4. **Align with regulatory frameworks** to ensure DoH deployment remains auditable and compliant.

Ultimately, the shift toward encrypted DNS is inevitable. Enterprises must prepare to integrate it into their architectures without compromising visibility, detection, or trust.

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